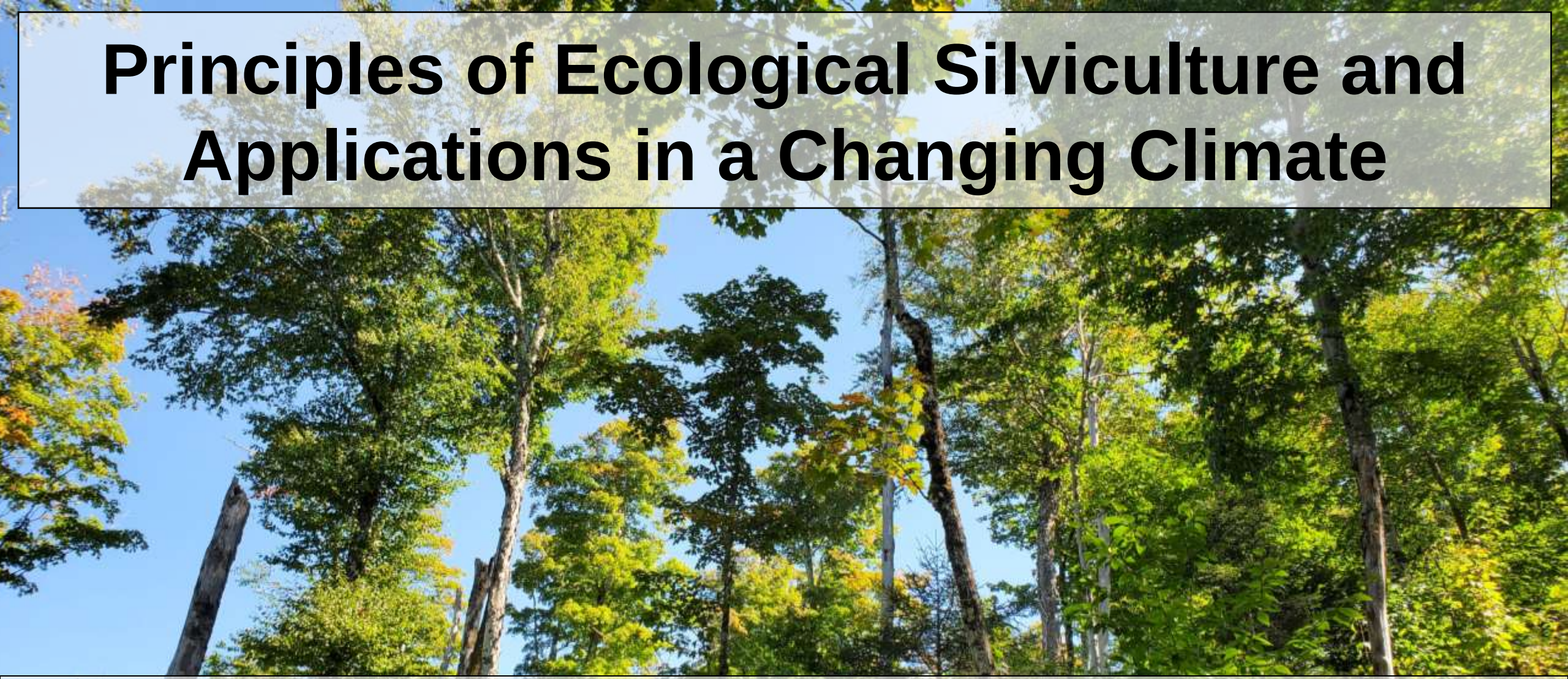
Principles of Ecological Silviculture and Applications in a Changing Climate



THE UNIVERSITY OF VERMONT FORESTRY

ASCC Adaptive Silviculture for Climate Change

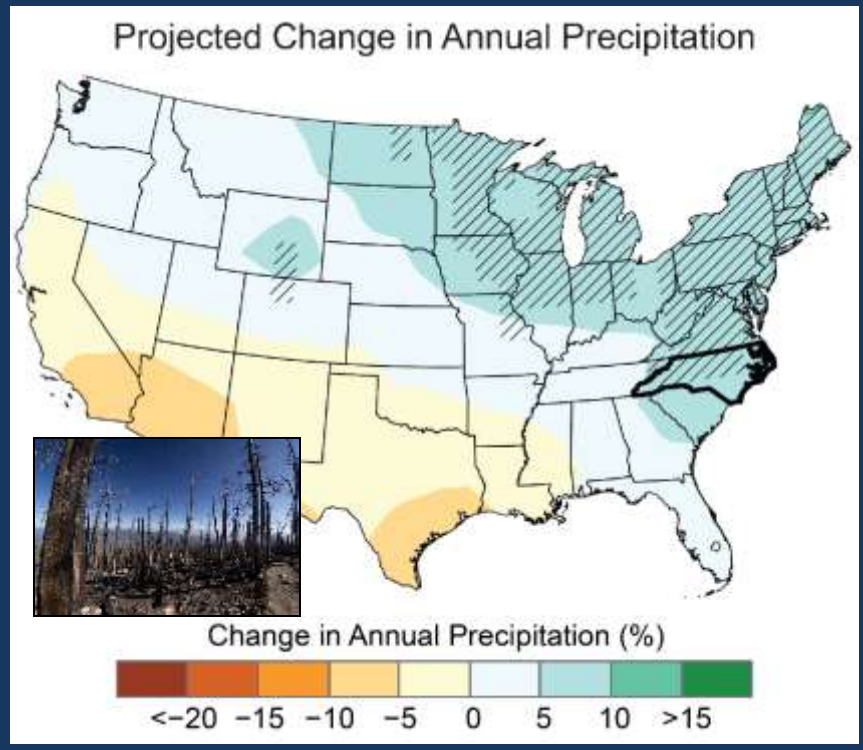
Tony D'Amato

Rubenstein School of Environment and Natural Resources
University of Vermont

NIACS Northern Institute of Applied Climate Science

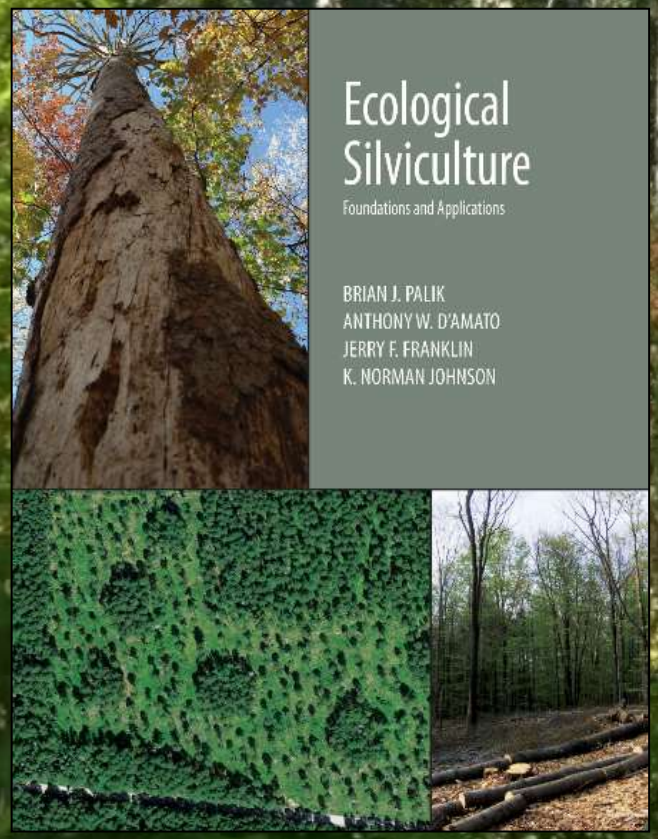
NECASC Northeast Climate Adaptation Science Center

21st Century Context for Ecological Silviculture

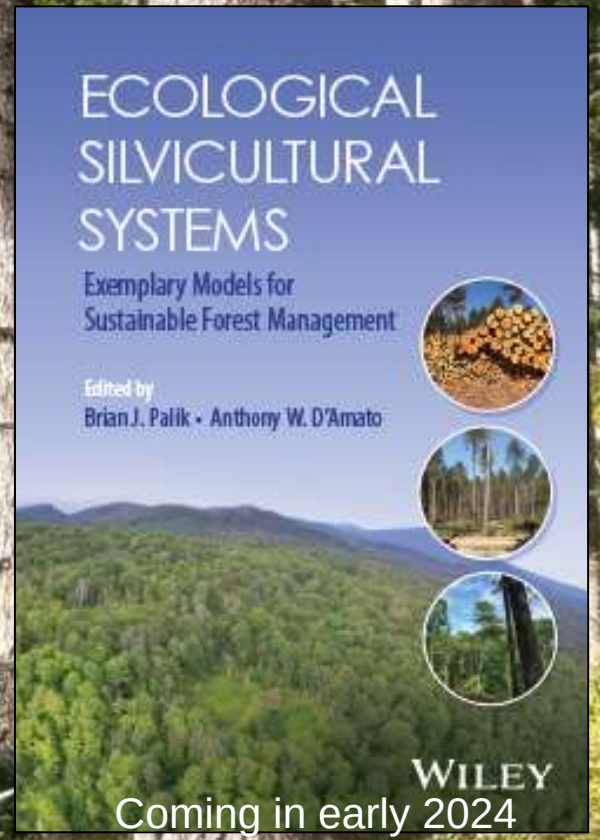


46% of wood consumed comes from plantations

Ecological Silviculture



Brian Palik
Jerry Franklin
Norm Johnson
Many others….



Coming in early 2024

Ecological Silviculture Defined

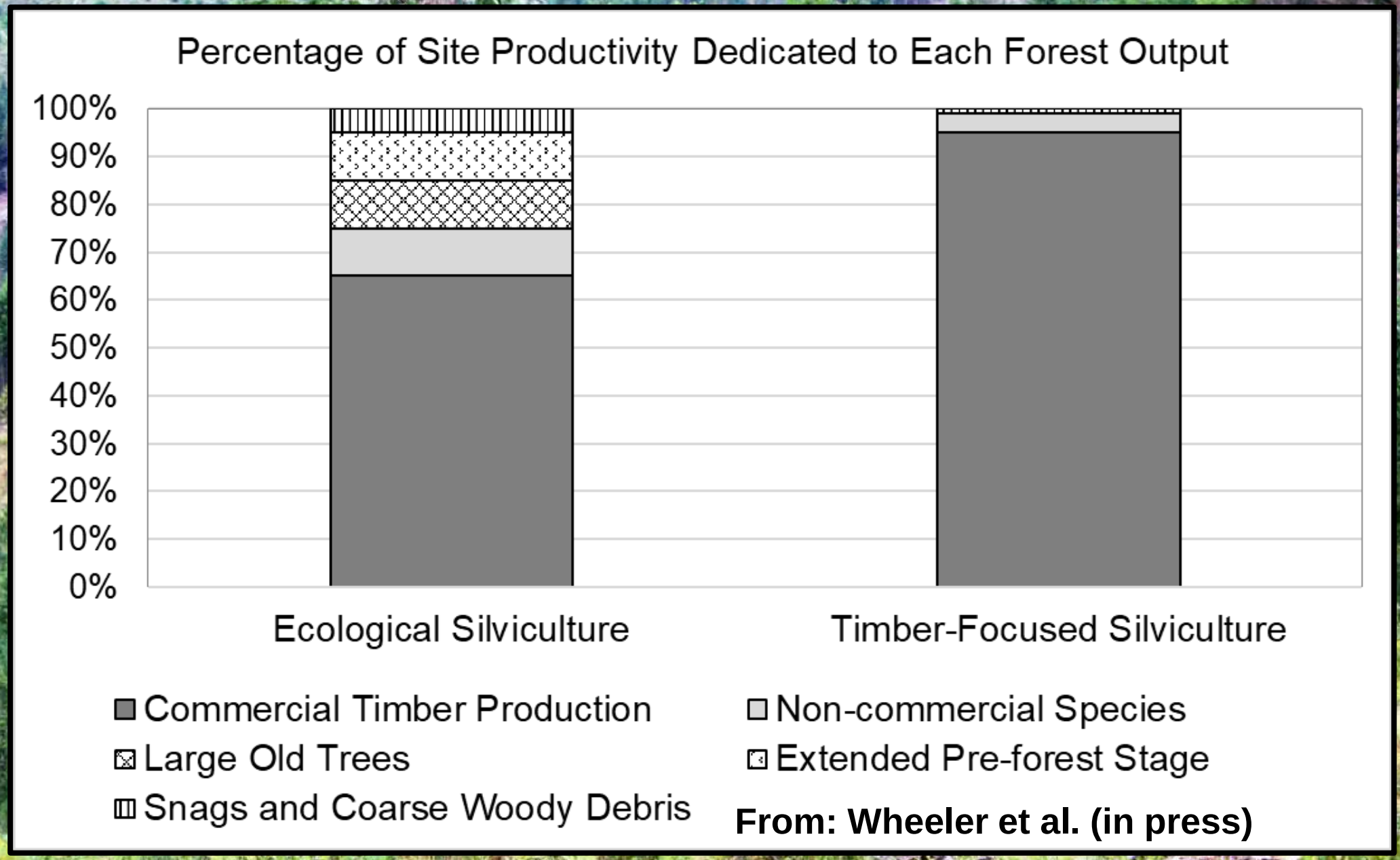
Management approach that applies an understanding of the structure, function, and dynamics of natural forest ecosystems to achieve integrated environmental, economic, and social outcomes (Palik et al. 2020)

Ecological vs. Timber-Focused Silviculture

Ecological forestry still includes removal of trees to produce forest products; however, guiding principles are different from timber-focused model

Ecological Forestry	Timber-Focused Forestry
Maintains ecosystems and their array of structures, functions (processes), and biota	Maintains a subset of ecosystem structures, functions, and biota consistent with economic goals
Uses natural stand development models, including effects of disturbances, as the basis for silvicultural prescriptions	Based on agronomic models, e.g., plant spacing, weeding, fertilization, as the bases for silvicultural prescriptions
Values complexity and heterogeneity of ecosystem attributes	Values simplicity and homogeneity of structure and composition
Emphasizes ecosystem diversity and resilience to reduce major disruption risks	Emphasizes optimizing growth of crop species to reduce risks

Palik et al. (2020)


Percentage of Site Productivity Dedicated to Each Forest Output
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Ecological Silviculture
Timber-Focused Silviculture
Commercial Timber Production
Large Old Trees
Snags and Coarse Woody Debris
Non-commercial Species
Extended Pre-forest Stage
From: Wheeler et al. (in press)

Operating principles of ecological silviculture

Operating principles of ecological silviculture

1. *Continuity*-provision for continuity in forest structure, function, and biota between pre- and post-harvest ecosystems during regeneration harvests

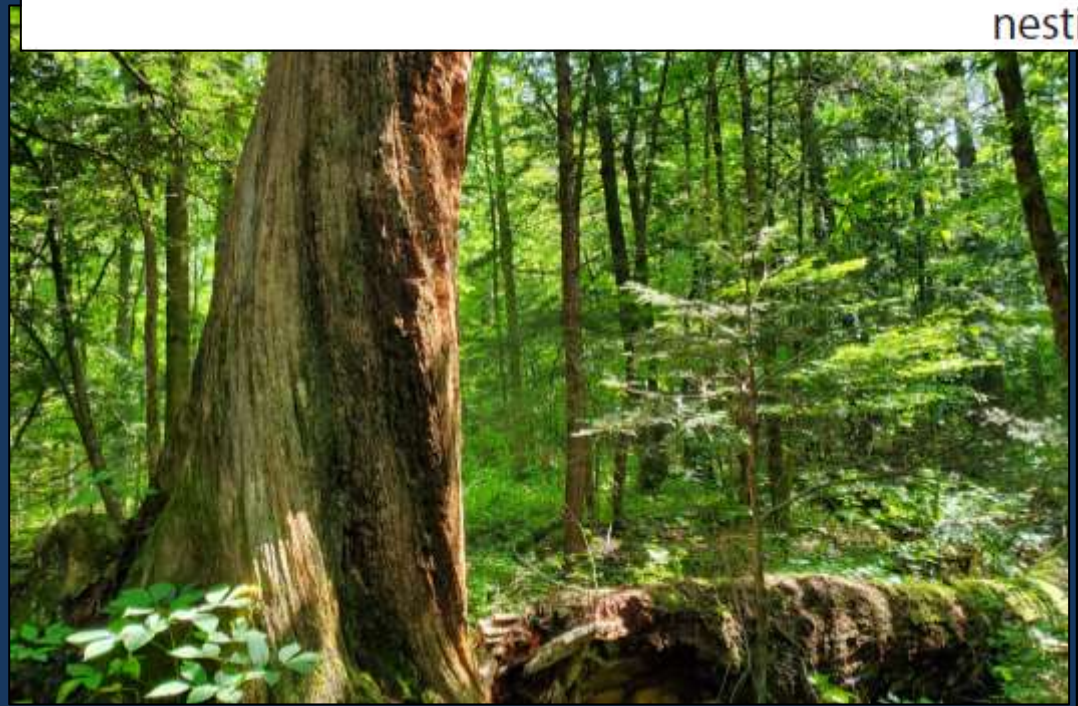
Emphasize what is left behind over what is removed

Leave trees, legacy trees, green trees, reserve trees, retention harvests

Leaving trees to die

Operating principles of ecological silviculture

Principle	Commodity productivity	Biodiversity conservation	Global change resilience/adaptation
1) Continuity	• Opportunities for natural regeneration of a range of species • Larger high-value products*	• Life boating of species requiring mature forest conditions • Greater diversity of food/energy sources from canopy species • Large snags/deadwood for saproxylic and cavity nesting species	• Options for regeneration in face of uncertainty • Amelioration of harsh environmental conditions ◦ regeneration safe sites (shaded understory, decomposed wood) • Conservation of genetic diversity

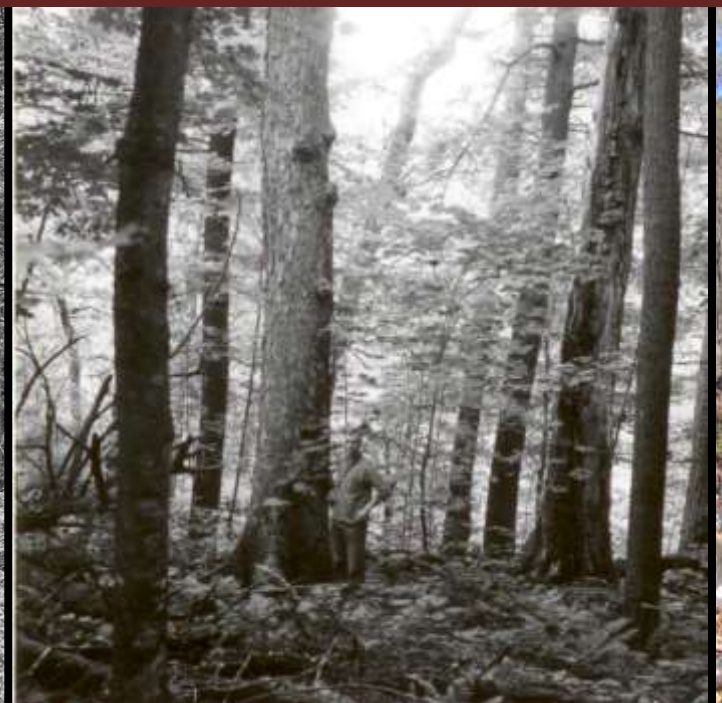


Operating principles of ecological silviculture

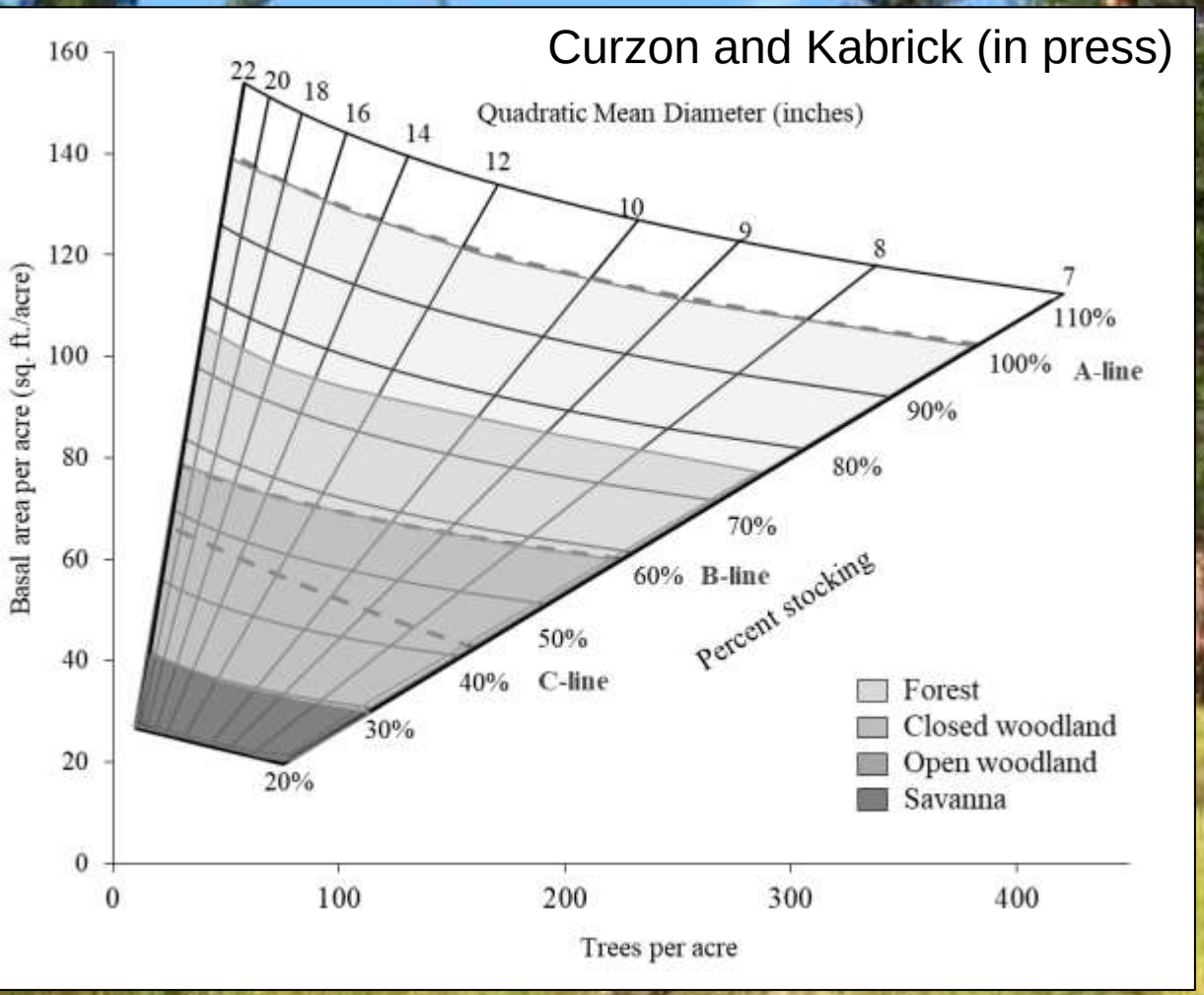
2. *Complexity/diversity*-create and maintain structural complexity and species diversity at multiple spatial scales through silvicultural treatments

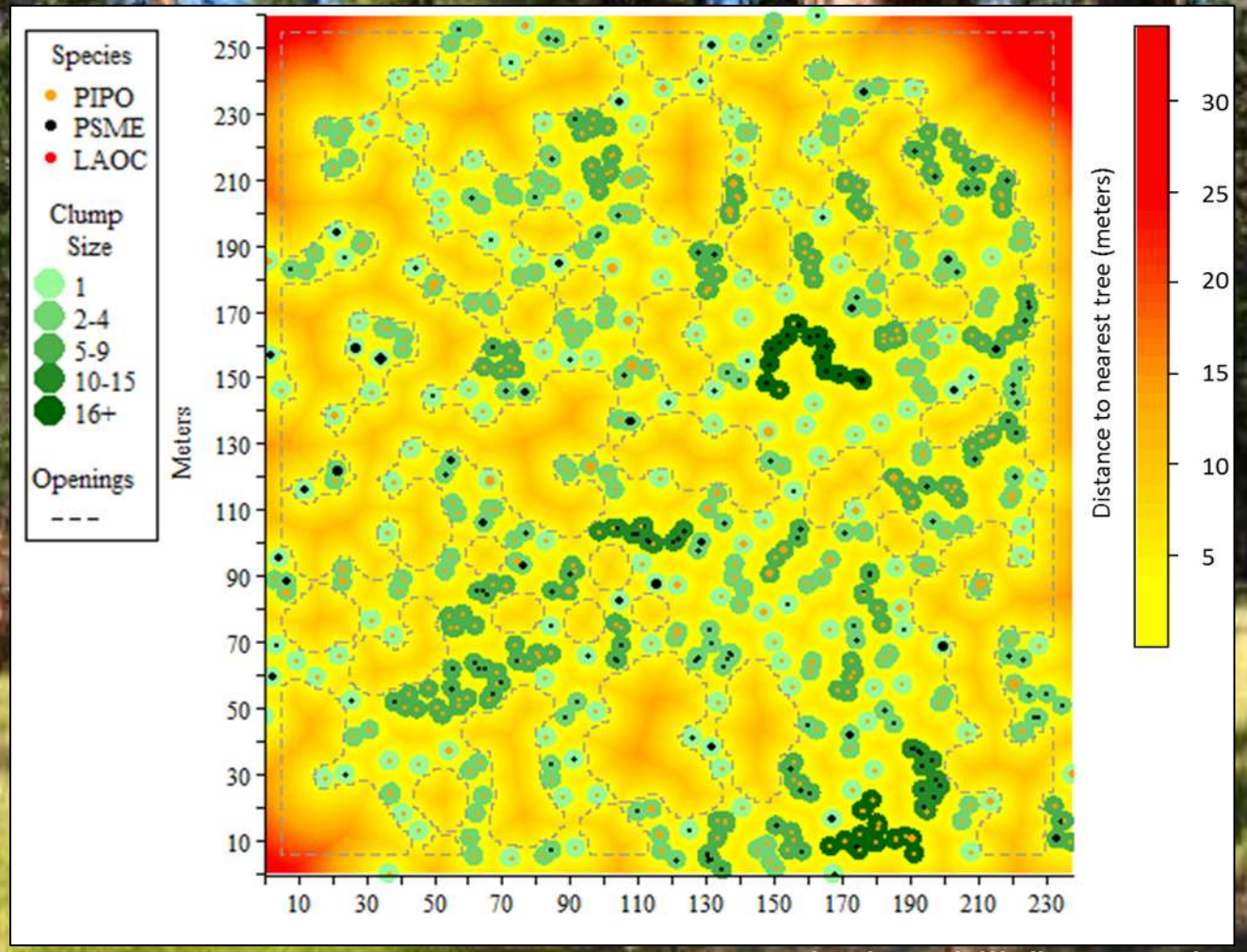


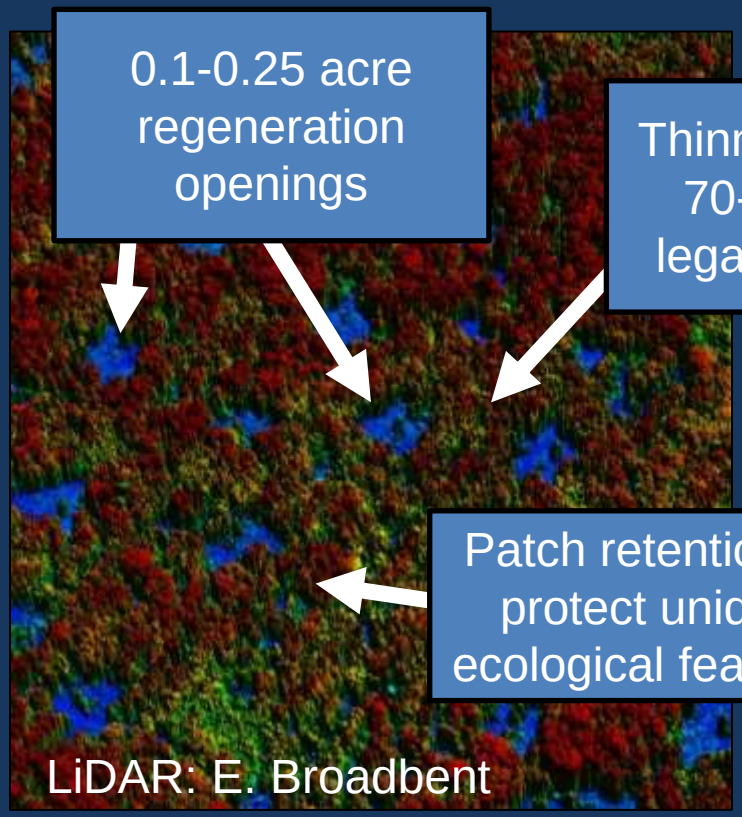
Our large-tree bias undersells complexity of natural forests

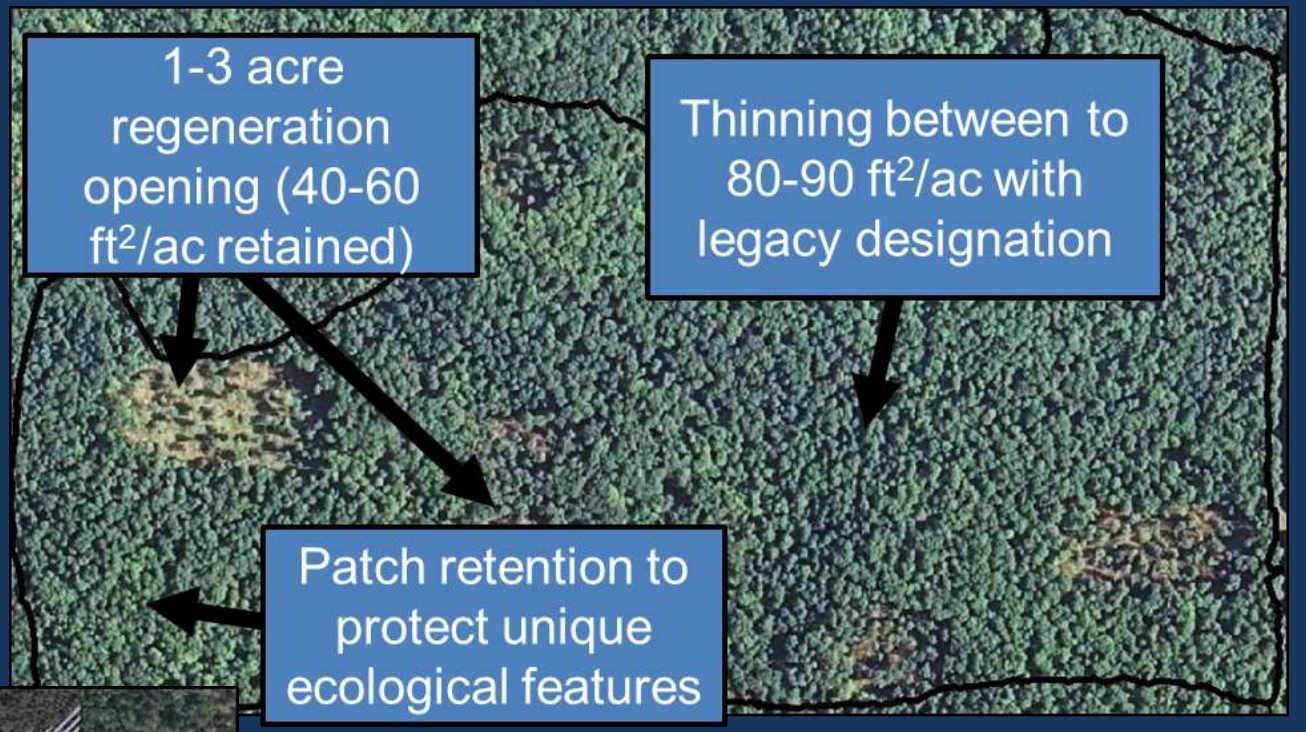



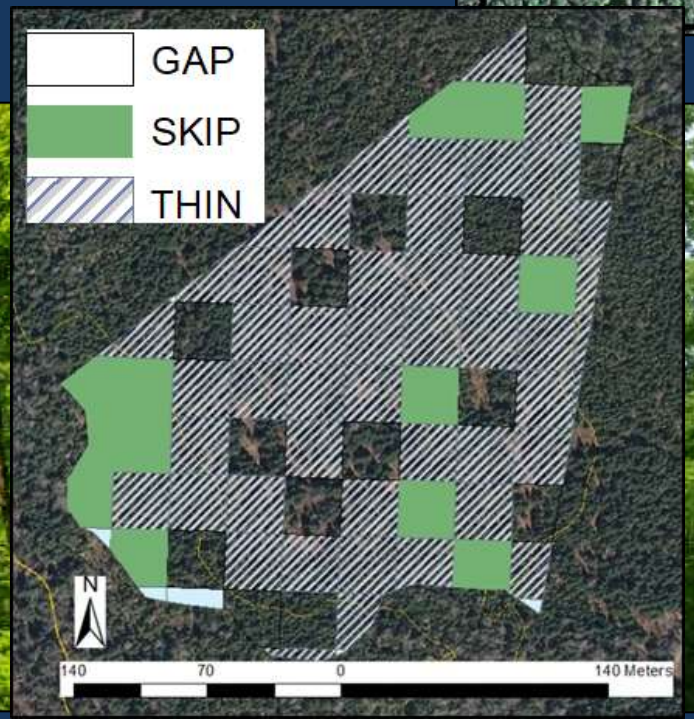
Variability in density and spatial pattern






0.1-0.25 acre regeneration openings
Thinning between to 70-80 ft²/ac with legacy designation
Patch retention to protect unique ecological features
LiDAR: E. Broadbent


1-3 acre regeneration opening (40-60 ft²/ac retained)
Thinning between to 80-90 ft²/ac with legacy designation
Patch retention to protect unique ecological features


GAP
SKIP
THIN
N
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70
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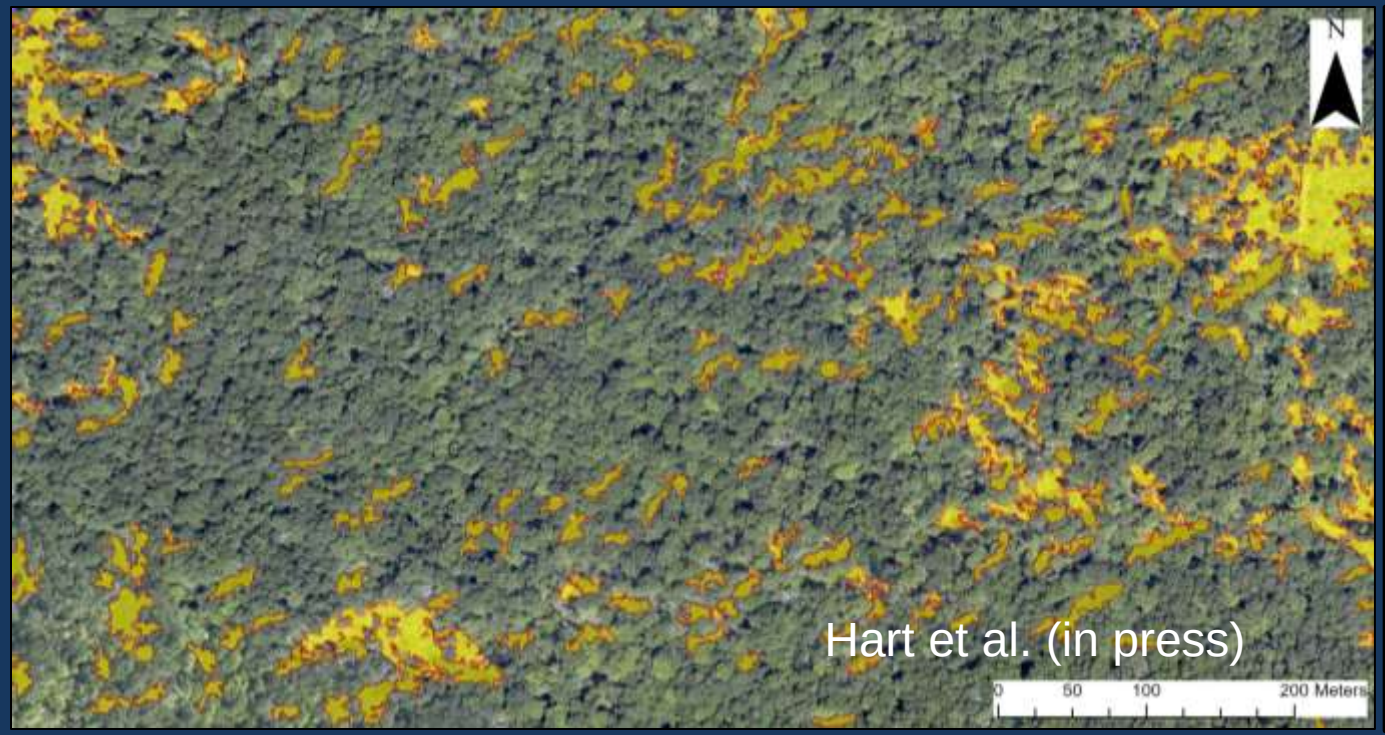
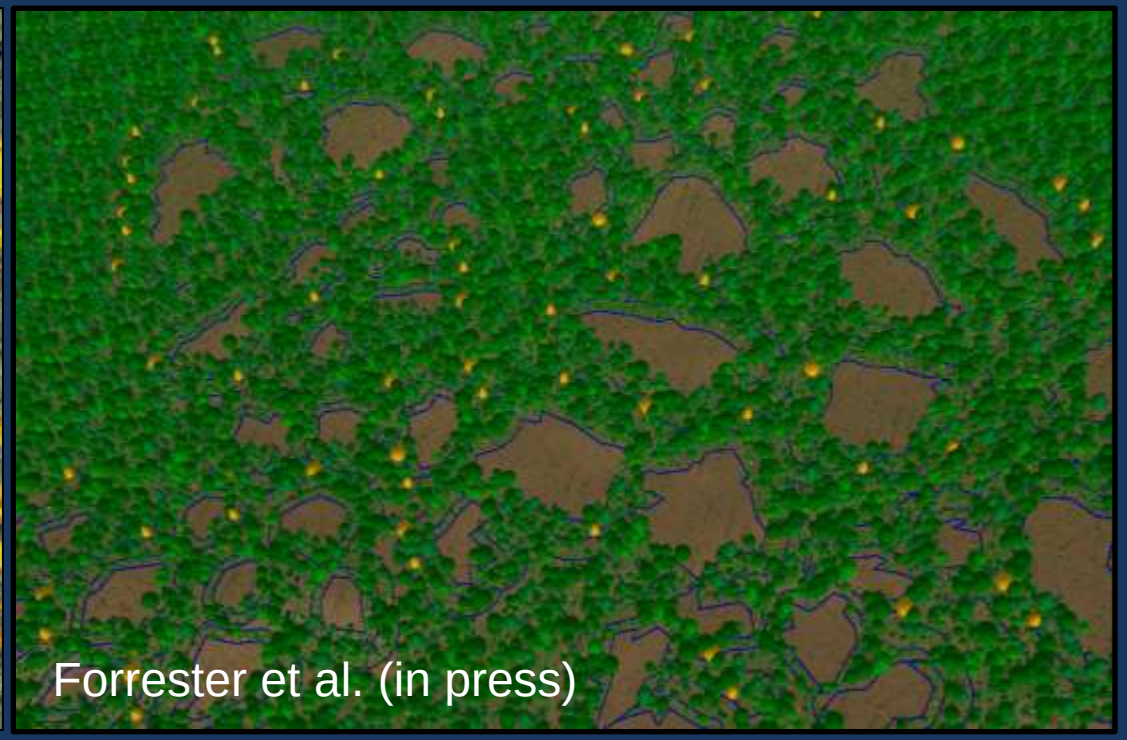
140 Meters



Hart et al. (in press)

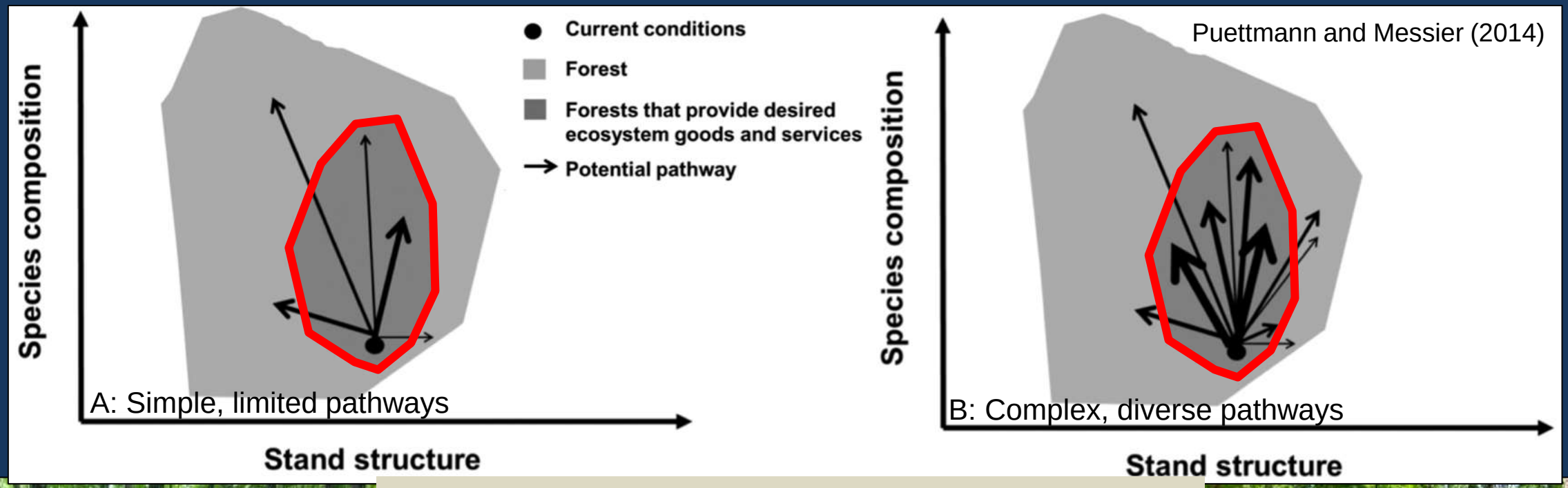

Forrester et al. (in press)


Forrester et al. (in press)

Operating principles of ecological silviculture

Principle	Commodity productivity	Biodiversity conservation	Global change resilience/adaptation
2) Complexity/ Diversity	• Opportunities for multiple entries (outputs) • Diverse product mix • High-quality products (resulting from natural pruning, training) • Multiple opportunities for natural regeneration of desired species	• Diversity of habitat niches ◦ tree size classes ◦ deadwood decay classes ◦ live-tree spatial conditions ◦ tree, shrub, understory species	• Reduced vulnerability to disturbance ◦ spatial variability in fuels ◦ heterogeneity in wind risk (diverse heights) ◦ heterogeneity in potential host species (insects/disease) ◦ heterogeneity of tree sizes (host preferences, stress tolerance) • Multiple Recovery and developmental pathways ◦ diversity of seed sources ◦ advance regeneration • High levels of onsite mitigation potential (carbon storage)

Forest complexity and recovery pathways



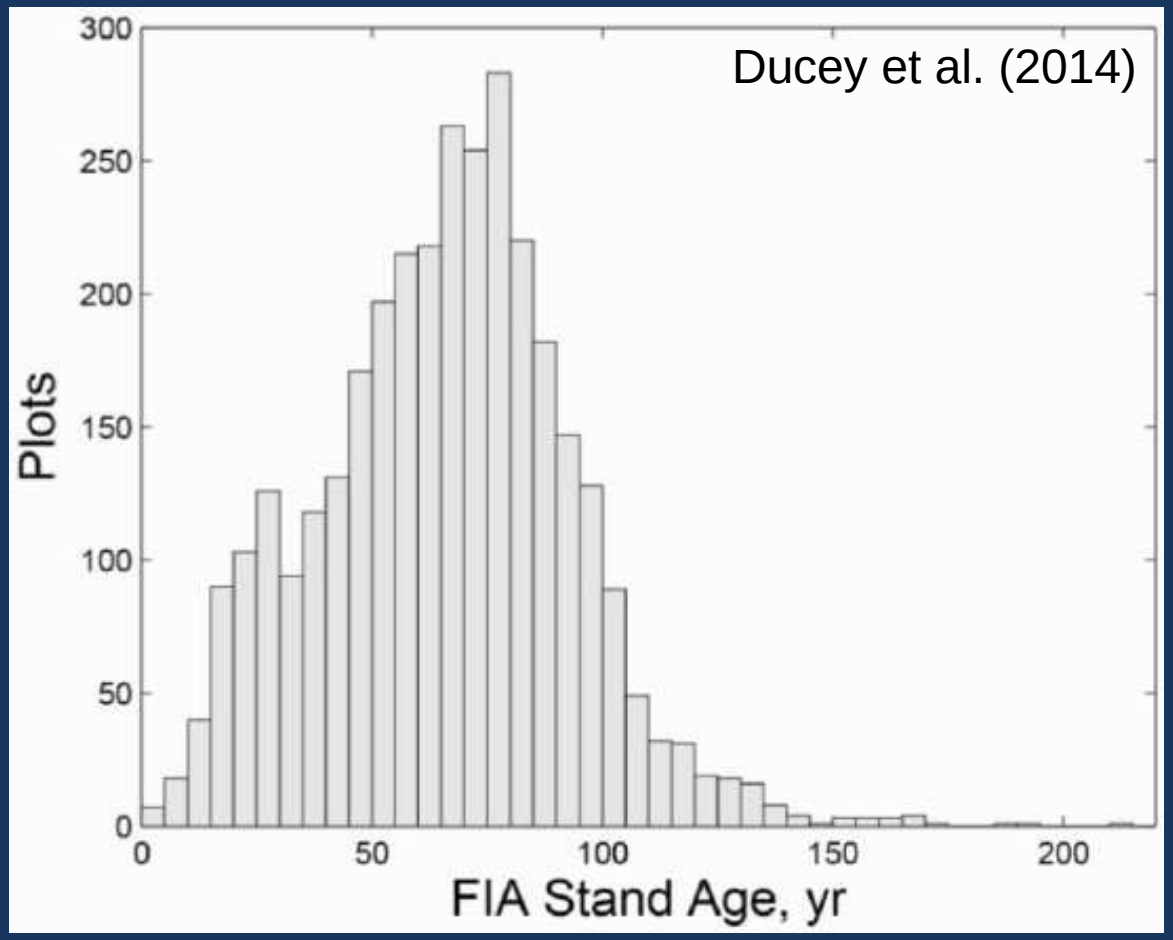
Puettmann and Messier (2014)

Increasing ecosystem complexity, increases amount and diversity of adaptation pathways for responding to change. Goal is to increase likelihood that pathway includes conditions providing desired ecosystem goods and services.

Question break

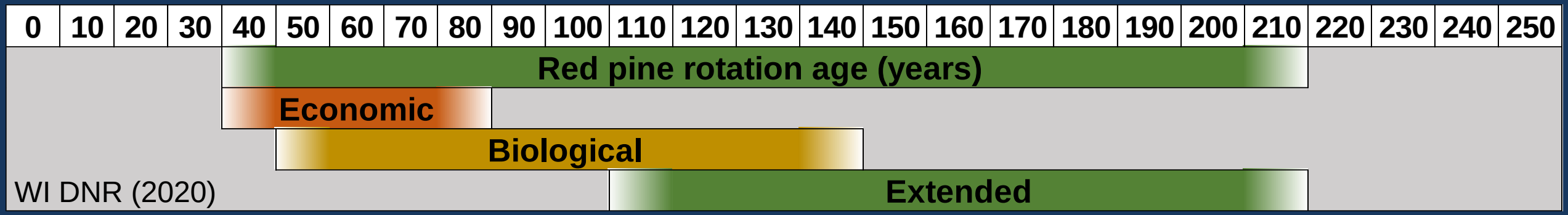
Operating principles of ecological silviculture

3. *Timing*-apply silvicultural interventions at ecologically appropriate time intervals



Large, old trees severely underrepresented in current landscapes

Extended Rotation Systems

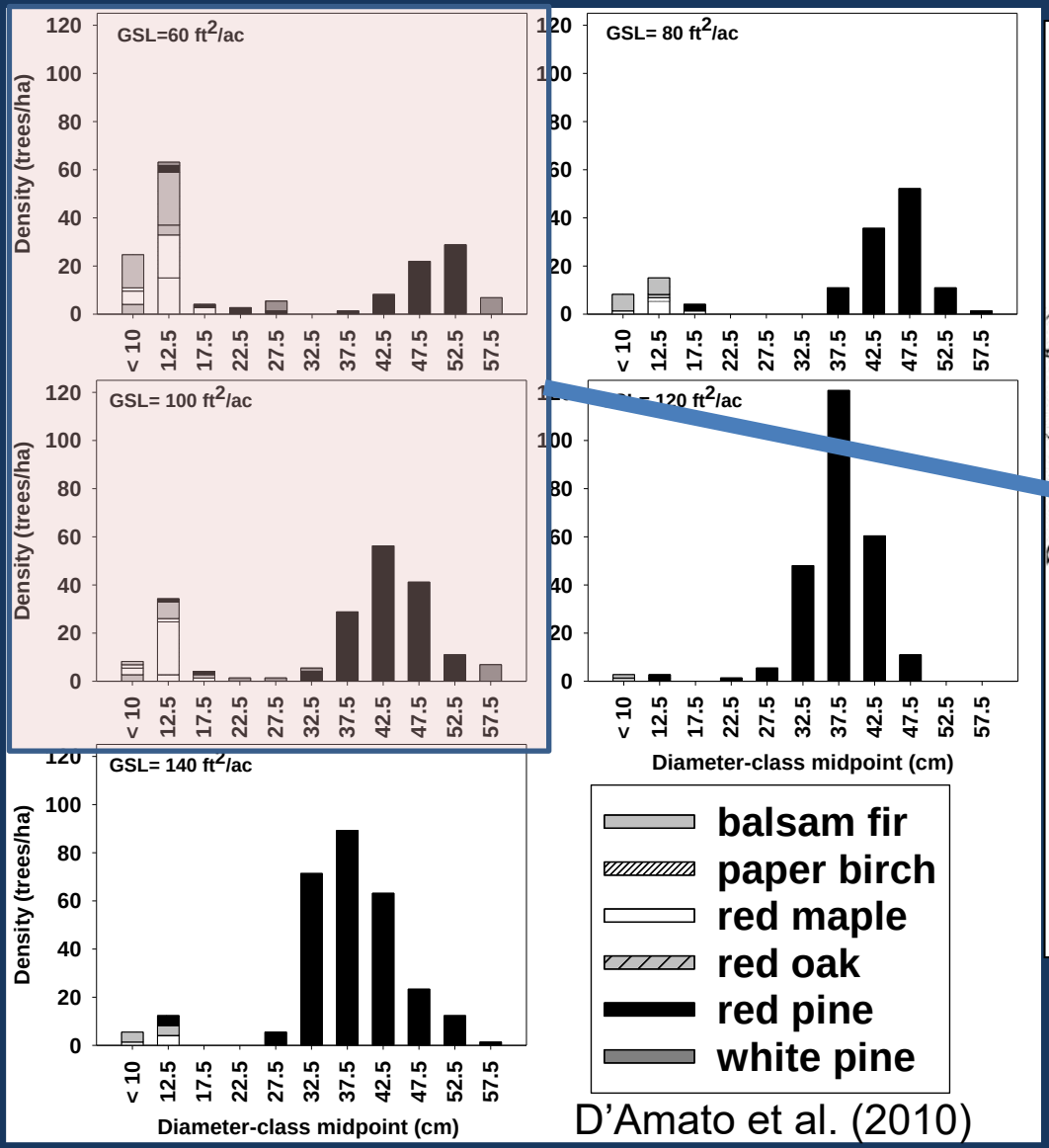


Criteria for determining rotation length

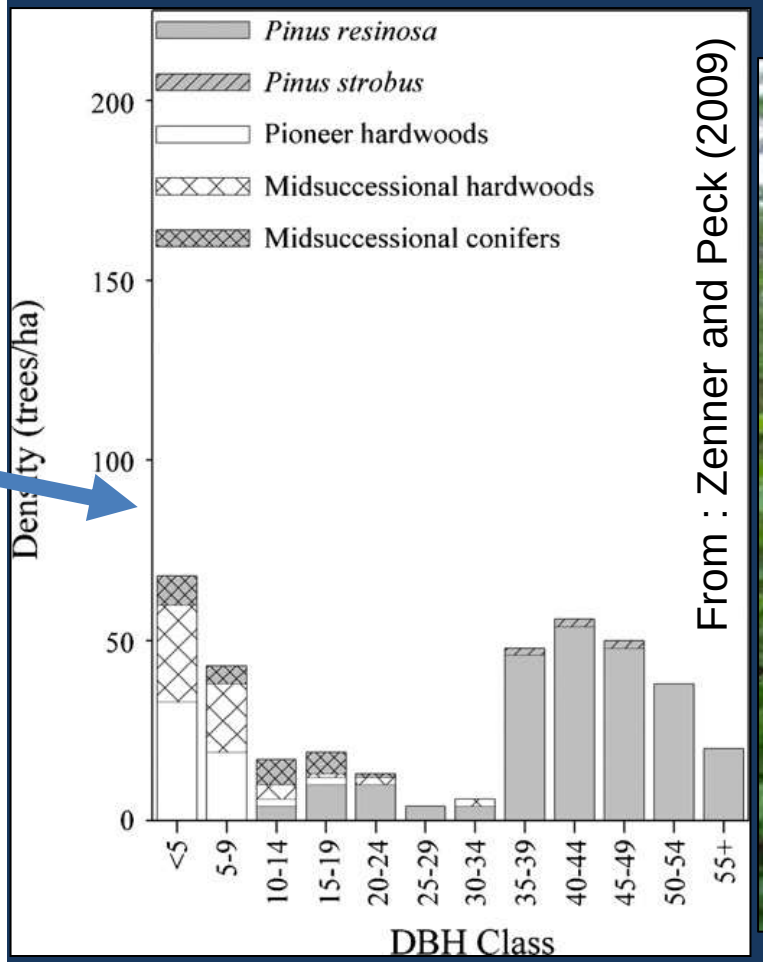
- **Economic**-rotation age based on maximum net present value
  - Based primarily on discount rate
- **Biological**-rotation age based on peak mean annual increment (maximum sustained yield)
  - Often determined from normal yield tables
- **Extended**-rotation age that exceeds biological rotation age
  - Determined based on ecological and economic objectives

Extended rotation systems

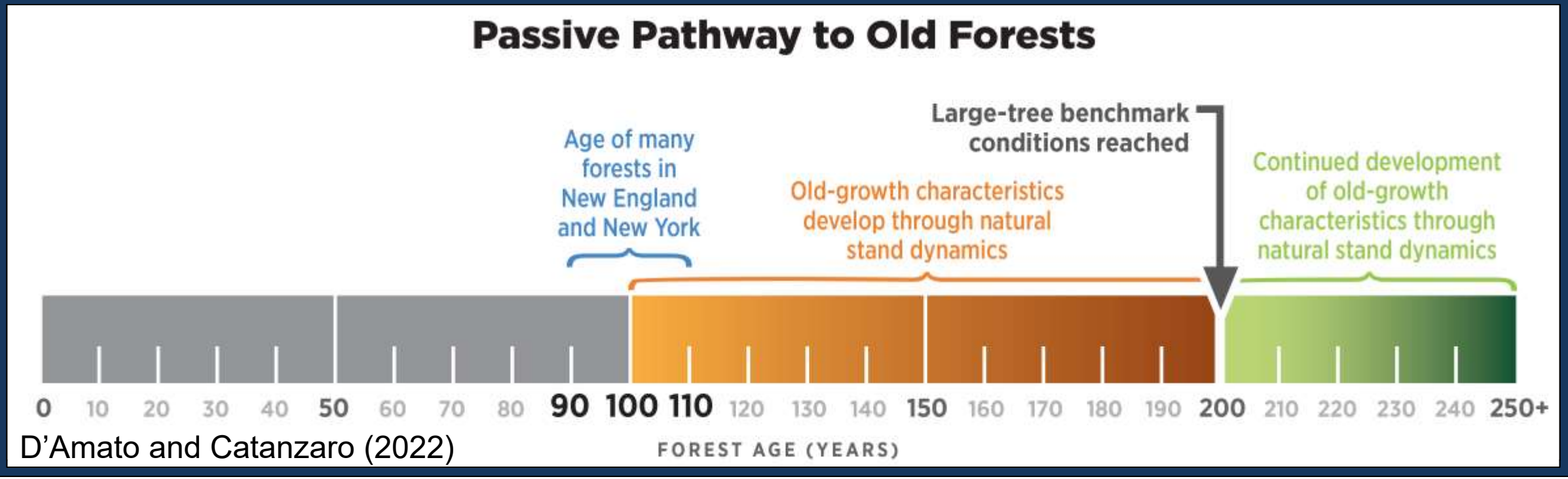
Restoration of late-successional forest conditions via extended rotations in red pine



D'Amato et al. (2010)



Old-growth red pine stand (> 300 years old), Itasca, MN



D'Amato and Catanzaro (2022)

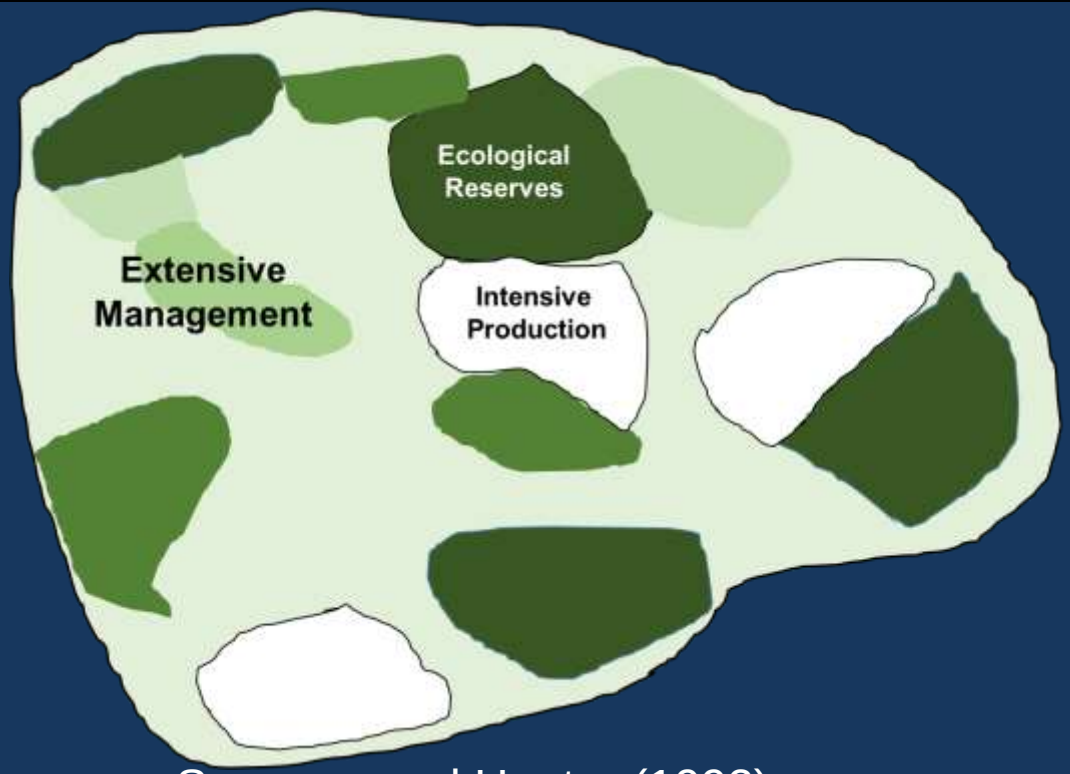
Operating principles of ecological silviculture

Principle	Commodity productivity	Biodiversity conservation	Global change resilience/adaptation
3) Timing	• Higher-value products • Multiple entries (outputs) • Seed source over extended periods • Multiple species and lifespans (diversity of products/harvests over time)	• Opportunity for multiple life cycles for species with slower development • Habitats for large tree specialists (live and dead trees)	• Long-term maintenance of options for adaptation from current overstory species • Long-term amelioration of extremes in understory conditions • Reduced likelihood for compounding influence of harvesting with other stressors/disturbance • Accumulation of large onsite carbon stores

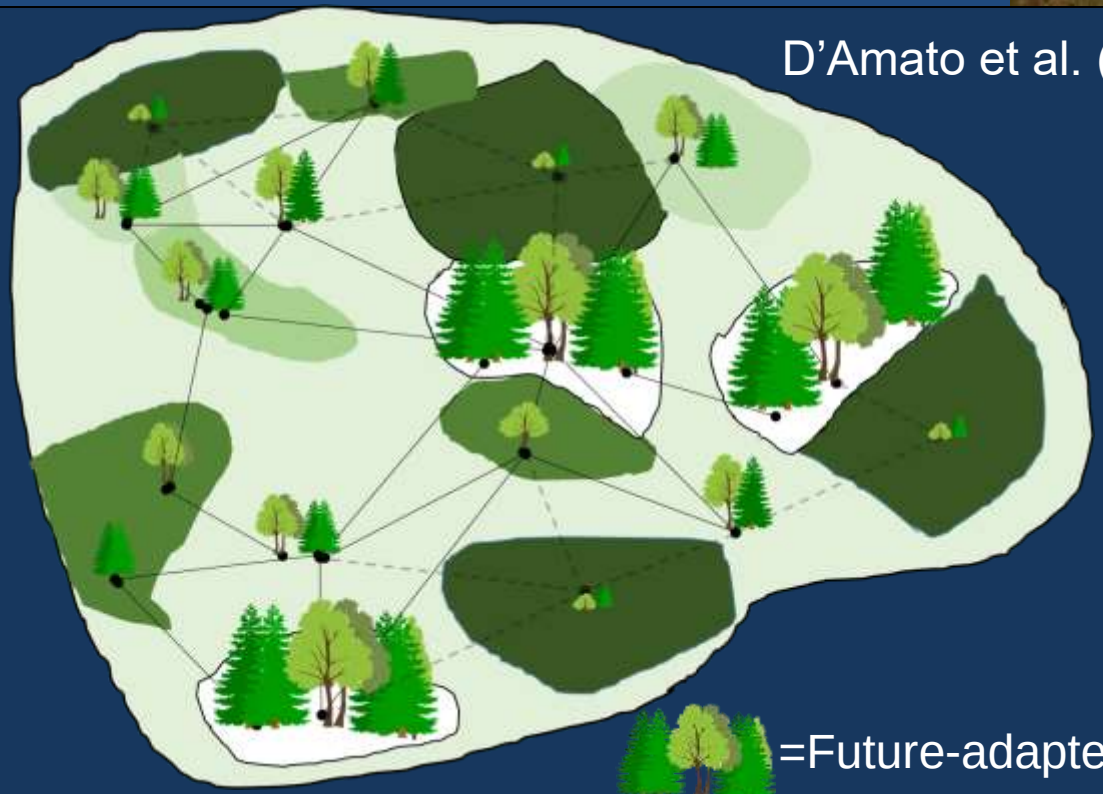
Operating principles of ecological silviculture

4. *Context*-plan and implement silvicultural interventions in the context of how these actions accumulate to influence landscape structure and function

Functional linkages between adaptation plantings

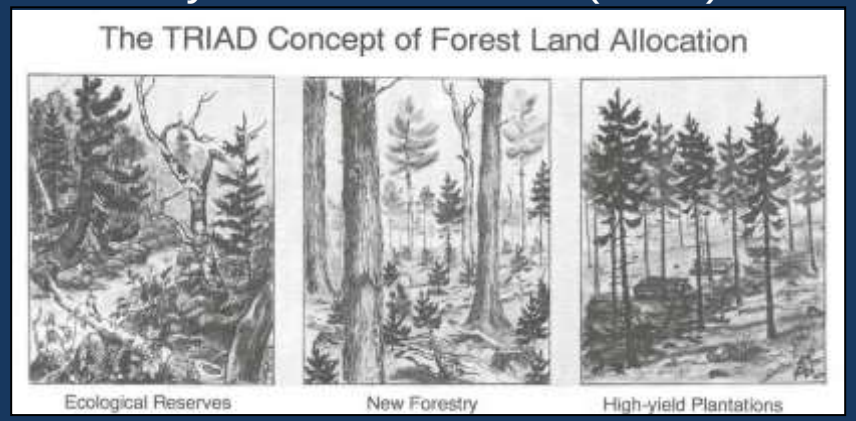


Seymour and Hunter (1992)



D'Amato et al. (2023)

=Future-adapted plantings



Operating principles of ecological silviculture

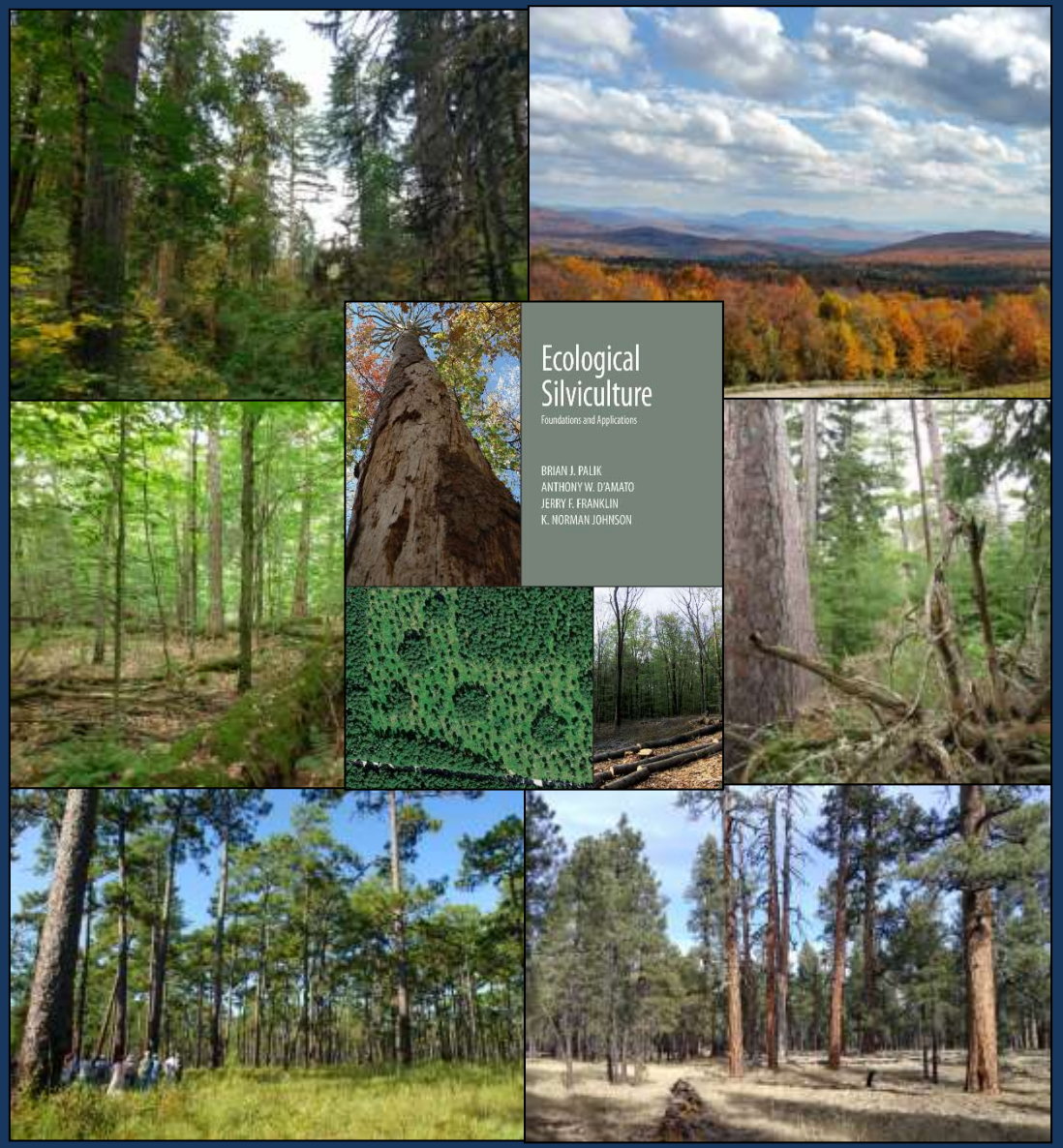
Principle	Commodity productivity	Biodiversity conservation	Global change resilience/adaptation
4) Context	• Diverse portfolio of products and potential harvest entries • Lower risk from changing market conditions	• Connectivity across landscapes and habitat gradients (e.g., riparian to upland, travel corridors) • Refugia at multiple scales • Diversity of structures/composition at landscape-scale	• Reduced risk from landscape-scale stressors (drought) and disturbance (insects, fire, wind) • Greater options for adaptation potential at broad scales • Greater range of regeneration conditions for new species due to localized and landscape-scale heterogeneity in structure


Simply retaining trees at harvest is not ecological silviculture!

Disturbance archetypes

Four predominant forest archetypes based on disturbance regime

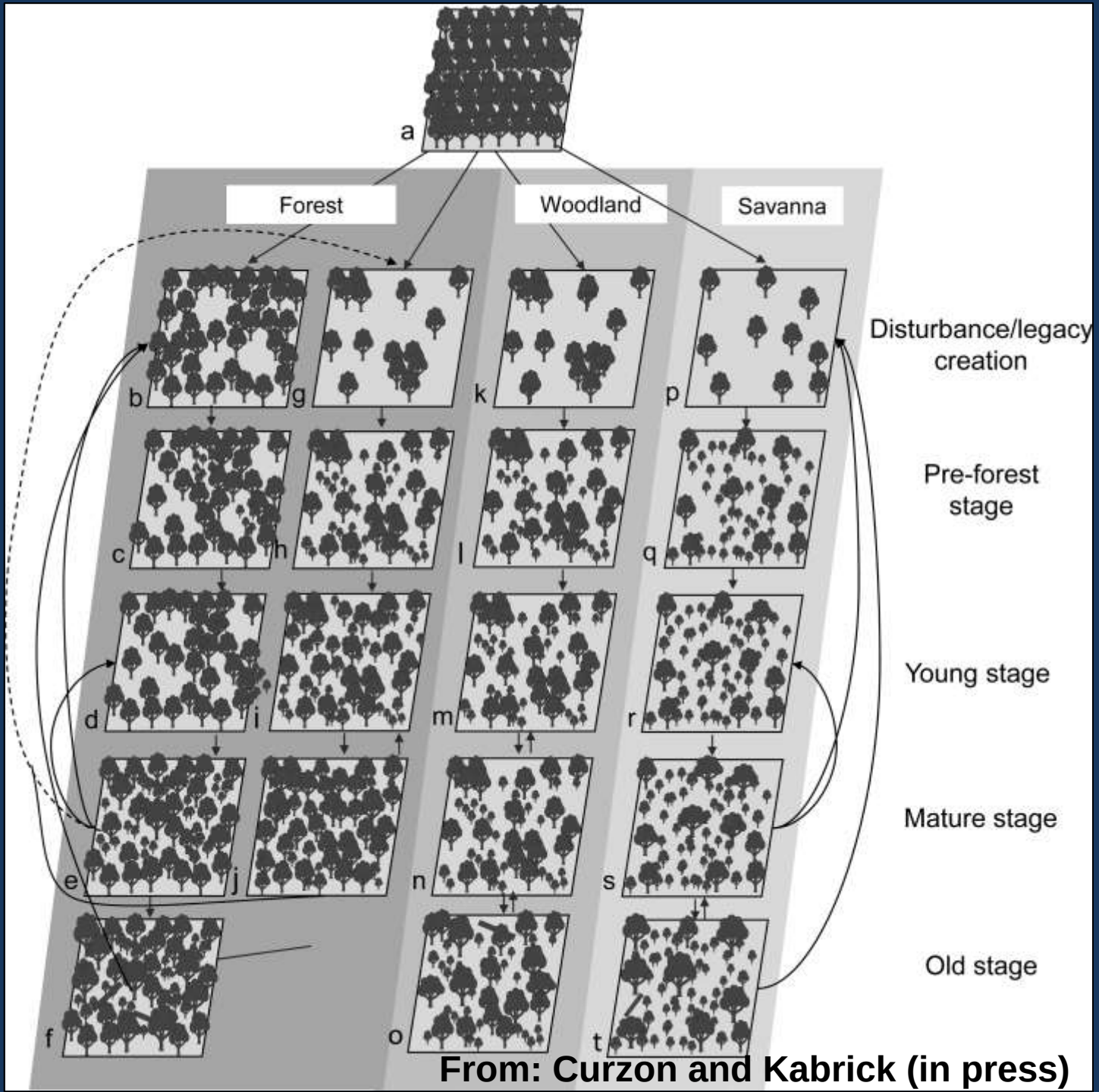
1. Forests initiated by infrequent severe disturbance
2. Forests characterized by frequent low-severity disturbance, primarily fire
3. Forests characterized by gap disturbance, notably from wind
4. Forests characterized by mixed-severity disturbance regimes



Ecological silvicultural systems

<u>Ecological silvicultural system</u>-long-term sequence of treatments for restoring, maintaining, and enhancing compositional diversity, ecological complexity, and heterogeneity

- Informed by understanding of natural disturbance dynamics and processes for a given community



From: Curzon and Kabrick (in press)

Photos: M. Curzon

Ecological silvicultural systems

Silvicultural systems across disturbance archetypes

D'Amato and Palik (in press)

Conclusions

- Ecological forestry at its core is about working *with* versus *against* a site and ecological system (i.e., localize things to your spot on the map)
- Increasing frequency and severity of disturbance requires greater emphasis on thoughtful, proactive and adaptive (vs reactive) ecological silviculture strategies
- Although based on “natural” systems, principles and outcomes of ecological silviculture provide useful building blocks for prescriptions that address novel challenges and objectives





Thanks!